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Original research

Association between population hypertension control and ischemic heart disease and stroke mortality in 36 countries of the Americas, 1990-2019: an ecological study

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ABSTRACT

Objective. To quantify the association between the prevalence of population hypertension control and ischemic heart disease (IHD) and stroke mortality in 36 countries of the Americas from 1990 to 2019.

Methods. This ecologic study uses the prevalence of hypertension, awareness, treatment, and control from the NCD-RisC and IHD and stroke mortality from the Global Burden of Disease Study 2019. Regression analysis was used to assess time trends and the association between population hypertension control and mortality.

Results. Between 1990 and 2019, age-standardized death rates due to IHD and stroke declined annually by 2.2% (95% confidence intervals: –2.4 to –2.1) and 1.8% (–1.9 to –1.6), respectively. The annual reduction rate in IHD and stroke mortality deaccelerated to –1% (–1.2 to –0.8) during 2000-2019. From 1990 to 2019, the prevalence of hypertension controlled to a systolic/diastolic blood pressure ≤140/90 mmHg increased by 3.2% (3.1 to 3.2) annually. Population hypertension control showed an inverse association with IHD and stroke mortality, respectively, regionwide and in all but 3 out of 36 countries. Regionwide, for every 1% increase in population hypertension control, our data predicted a reduction of 2.9% (–2.94 to –2.85) in IHD deaths per 100 000 population, equivalent to an averted 25 639 deaths (2.5 deaths per 100 000 population) and 2.37% (–2.41 to –2.33) in stroke deaths per 100 000 population, equivalent to an averted 9 650 deaths (1 death per 100 000 population).

Conclusion. There is a strong ecological negative association between IHD and stroke mortality and population hypertension control. Countries with the best performance in hypertension control showed better progress in reducing CVD mortality. Prediction models have implications for hypertension management in most populations in the Region of the Americas and other parts of the world.

Keywords Hypertension; cardiovascular diseases; mortality; noncommunicable diseases; Americas

In 2019, ischemic heart disease (IHD) and stroke were the first- and the second-leading causes of death, and the first- and the fourth-leading causes of disability-adjusted life years (DALYs), respectively, in the Region of the Americas (1,2). However, although age-standardized death and DALY rates for cardiovascular disease (CVD) decreased substantially between

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1990 and 2017, there has been a slowdown and stagnation in the rate of reduction in recent years. In addition, important disparities between and within countries in the Americas persist (3). This observation is concerning because of the effect of the CVD burden on life expectancy and healthy life expectancy, especially in people aged 65+ years (4). These findings suggest that traditional risk-reduction strategies for the prevention of CVD, population high risk, and health system strategies, are not working sufficiently well and that new approaches are urgently needed to reduce the burden of CVD-related disease in the general population.

CVD burden is influenced by genetic, metabolic, behavioral, environmental, and social determinants. However, high blood pressure plays a central role as a risk factor for CVD. Elevated systolic blood pressure (SBP) starting at an SBP ≥ 115 mmHg is the leading cause of DALYs globally and in the Americas (5,6). Suboptimal blood pressure (BP) control is the most important population attributable risk factor (PAF) for CVD and stroke, including hemorrhagic (PAF=58%) and ischemic (50%) stroke, ischemic heart disease (55%), and for other forms of CVD (58%) (7). Prevention and control of high BP can be accomplished by applying population-based and high-risk health services strategies, involving interventions to increase individuals' awareness, treatment, and control of CVD risk factors, including hypertension (8).

In 2017, the World Health Organization launched the Global HEARTS Initiative (9) to accelerate the reduction in burden of illness due to CVD. HEARTS in the Americas (10) is a regional adaptation of this initiative, which is being implemented in more than 1 300 primary health care centers in 22 countries. Its main purpose is to implement the best practices to improve the control of hypertension and other CVD risk factors, including diabetes, with the goal of reducing the burden of illness due to CVD. Monitoring trends in population hypertension control and in IHD and stroke mortality and understanding the dynamics of their association is essential to guiding the program's implementation and for monitoring and evaluation of progress.

An ecological association between population hypertension control and IHD and stroke mortality has been reported previously (11,12). To the best of our knowledge, however, no previous study has focused on countries in the Americas, nor with a large number of countries over a long-time frame. We aimed to describe the trend in IHD and stroke mortality, and the prevalence of population hypertension control by sex at regional and national levels from 1990 to 2019, and to quantify the association between the prevalence of the population hypertension control and IHD and stroke mortality in the Americas as a way to inform programmatic and policy development.

METHODS

Data sources

This is an ecological study using data from two separate sources. We obtained estimates on deaths caused by IHD, and stroke and stroke subtypes –e.g., ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage– by age and sex for the Region of the Americas and the 36 countries and territories of the Region (See list of locations, in supplementary material) from 1990 to 2019 from the Global Burden of Diseases, Injuries, and Risk Factors Study 2019 (GBD) (1). The GBD methods and data sources and those for CVD, IHD, and stroke-specific estimates, including data quality, are published elsewhere (5,6,13). In brief, GBD is a comprehensive epidemiological study that produces estimates of standard epidemiological measures for 369 diseases and injuries by age and sex for 204 countries and territories. For fatal disease estimates, GBD used vital registration and verbal autopsy data as inputs into the Cause of Death Ensemble modeling (CODEm) framework (14) to estimate deaths due to IHD, stroke and stroke subtypes. Deaths from vital registration systems coded to impossible or intermediate causes of death or unspecified conditions were reassigned using statistical methods. Data were extracted using the GBD Results Tool (http://ghdx.healthdata.org/gbd-results-tool).

We obtained estimates of the crude and age-standardized prevalence of hypertension and hypertension treatment cascade by sex for the Region of the Americas and 36 countries and territories from the WHO Global Health Observatory (15). The data sources, including information on available national risk factors surveys, and methods are described elsewhere (16). In brief, the primary outcome measures were the prevalence of hypertension, the proportion of people with hypertension who reported a previous hypertension diagnosis (awareness), who was taking medication for hypertension (treatment), and whose blood pressure was controlled (control) (17). Hypertension was defined as having SBP 140 mmHg or greater, a diastolic blood pressure (DBP) 90 mmHg or greater, or taking medication for hypertension. Control was defined as taking medication for hypertension and having SBP less than 140 mmHg and DBP less than 90 mmHg. These outcome indicators were estimated by sex for adults aged 30 to 79 years in countries from 1990 to 2019. Age-standardized prevalence of hypertension, awareness, treatment, and control were calculated by weighting age-specific estimates using the WHO standard population (18). In our study, we conducted a secondary data analysis using publicly available data, so it does not require ethical consent.

Countries were classified into five groups according to the socio-demographic index (SDI) (19) in 2019. SDI is a composite index of the overall development that positions all locations on a spectrum of socioeconomic development, using average educational attainment over age 15 years, lagged distributed income, and total fertility rate under age 25 years generated by the GBD study. The SDI ranges from 0 to 1, where 0 represents the lowest income per capita, lowest educational attainment and highest fertility observed, and 1 represents the highest income per capita, highest educational attainment and lowest fertility observed, across all GBD geographies from 1980 to 2019.

Analytic strategies/Statistical analysis

We examined the age-standardized death rates (ASDR) per 100 000 population for IHD, overall stroke and stroke subtypes. Separately, we examined the age-standardized prevalence of hypertension, awareness, treatment, control among treated, and population hypertension control. All measures were stratified by sex and country from 1990 to 2019.

We assessed time trends for each outcome measure using the average annual percent change (AAPC), a summary measure of trend. We estimated the AAPC and its 95% confidence intervals (CI) by separately fitting a log-linear model to the

age-standardized death rates per 100 000 population for IHD and stroke, the prevalence of hypertension, awareness, treatment, control among treated, and population control on year by sex and country for three periods (1990-1999, 2000-2009, and 2010-2019), with the slope of the line providing AAPC per the following equation:

$$AAPC_{c,s,p} = \{\exp(b_{c,s,p}) - 1\} \times 100$$

Where b is the slope of the fitted regression line for a country c, sex s, and period p. AAPC is interpreted as an increasing trend when AAPC 95% CI are higher than zero, constant trend when AAPC 95% CI overlap with zero, and decreasing trend when AAPC 95% CI are lower than zero.

We applied regression modeling to quantify the association between the prevalence of population hypertension control and IHD and stroke mortality by sex at regional and national levels from 1990 to 2019. Three regression models (linear-linear, log-linear, and linear-log) were fitted to the empirical data. The log-linear (exponential) model was selected as it showed the lowest sums of squared errors, mean squared errors, and standard error of estimates. The regional best-fitted regression model was used for predicting the expected level of IHD and stroke mortality for a given level of population hypertension control, and as a counterfactual scenario for assessing the performance of the national cardiovascular care program. The slope and corresponding 95% CI (expressed in percentage) of the regression line, the coefficient of determination (R-squared), and the regression equation were reported. A sensitivity analysis of the regression modeling including countries with high-quality data validated the resulting association.

RESULTS

Ischemic heart disease and stroke mortality

Regionwide from 1990 to 2019, the ASDR due to IHD and stroke significantly declined with an AAPC of –2.2% (95% CI: –2.4 to –2.1) and –1.8% (–1.9 to –1.6), respectively. However, reduction rates deaccelerated in the latest decade (2010-2019) to –1.0% (–1.2 to –0.8) for both IHD and stroke, a pattern observed in both men and women (Table 1).

Figure 1 shows ASDR for IHD and stroke combined in 2019. Bars were broken down by IHD and stroke subtypes and countries were ranked in descending order by ASDR in each sex. At the top, Haiti, Guyana, the Dominican Republic and Honduras had the highest mortality, and at the bottom, Peru, Puerto Rico, Canada and Chile had the lowest mortality for both sexes. The difference in ASDR between both groups was greater than three-fold. Caribbean countries ranked among the top third with the highest mortality, except Barbados for women. Among the most populous countries in the Region, Canada and the United States had mortality below the regional average, while Mexico and Brazil were slightly above the regional value for men and women.

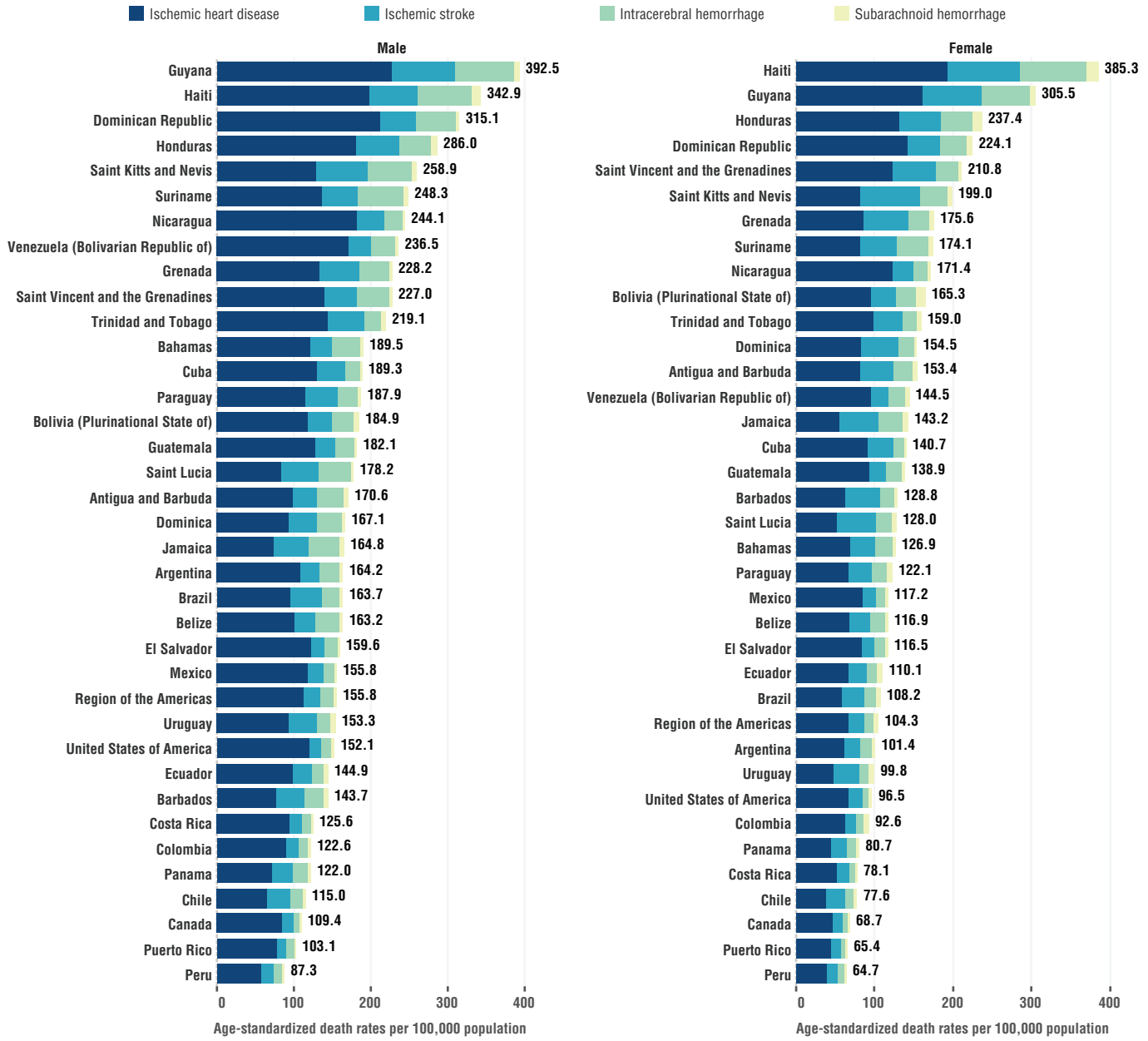
There was a positive association between the ASDR from IHD and stroke in 2019 and their corresponding AAPC in 2010-2019. Countries that achieved a large reduction in rates (AAPC<0) reached low mortality in 2019. This trend was observed in both men and women (Figure 2). For IHD, Chile, and Canada, in both sexes, represent the best-performing countries. On the other hand, Peru and Colombia show the best performance for stroke, combining the lowest ASDR in 2019 and the higher annual reduction rates (lowest AAPC) between 2010 and 2019.

TABLE 1. Age-standardized death rates (ASDR) for ischemic heart disease, stroke and stroke subtypes in 2019 and average annual percent change in the period 1990-2019 and 2010-2019 by sex in the Region of the Americas

		Age-standardized death rates per 100 000 population (95% UI)	Average annual percentage change (95% UI)	
Sex	Cause	2019	1990-2019	2010-2019
Both sexes				
	Ischemic heart disease	87.5 (79.1 – 93.3)	–2.2 (–2.4 to –2.1)	–1.0 (–1.2 to –0.8)
	Stroke	40.3 (36.2 – 43.1)	–1.8 (–1.9 to –1.6)	–1.0 (–1.2 to –0.8)
	Ischemic stroke	21.7 (18.8 – 23.4)	–2.0 (–2.1 to –1.9)	–1.0 (–1.2 to –0.7)
	Intracerebral hemorrhage	14.1 (13.0 – 15.0)	–1.8 (–1.9 to –1.6)	–1.1 (–1.3 to –0.9)
	Subarachnoid hemorrhage	4.6 (4.2 – 4.9)	–0.6 (–0.7 to –0.6)	–0.4 (–0.5 to –0.4)
Male				
	Ischemic heart disease	112.4 (103.6 – 119.6)	–2.2 (–2.3 to –2.1)	–0.9 (–1.1 to –0.7)
	Stroke	43.4 (39.8 – 46.2)	–1.8 (–2.0 to –1.7)	–0.9 (–1.1 to –0.7)
	Ischemic stroke	22.6 (20.2 – 24.2)	–2.1 (–2.2 to –1.9)	–1.0 (–1.2 to –0.8)
	Intracerebral hemorrhage	16.4 (15.2 – 17.6)	–1.8 (–1.9 to –1.6)	–1.0 (–1.2 to –0.8)
	Subarachnoid hemorrhage	4.3 (3.6 – 4.7)	–0.4 (–0.5 to –0.3)	–0.2 (–0.2 to –0.1)
Female				
	Ischemic heart disease	66.9 (58.7 – 72.3)	–2.3 (–2.5 to –2.2)	–1.2 (–1.5 to –1.0)
	Stroke	37.5 (33.0 – 40.5)	–1.8 (–2.0 to –1.6)	–1.0 (–1.1 to –0.8)
	Ischemic stroke	20.6 (17.5 – 22.5)	–1.9 (–2.0 to –1.8)	–0.9 (–1.1 to –0.7)
	Intracerebral hemorrhage	12.0 (10.9 – 12.9)	–1.8 (–2.0 to –1.7)	–1.3 (–1.5 to –1.1)
	Subarachnoid hemorrhage	4.8 (4.4 – 5.2)	–0.8 (–0.9 to –0.7)	–0.6 (–0.7 to –0.4)

Source: prepared by the authors based on estimates of the GBD Study 2019 and results of this study. Age-standardized death rates per 100 000 population are presented with one decimal places and the average annual percentage change is shown in one decimal place.
95% UI, 95% uncertainty intervals of the point estimates

FIGURE 1. Age-standardized deaths per 100 000 population for ischemic heart disease, stroke, ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage in 2019 by country and sex



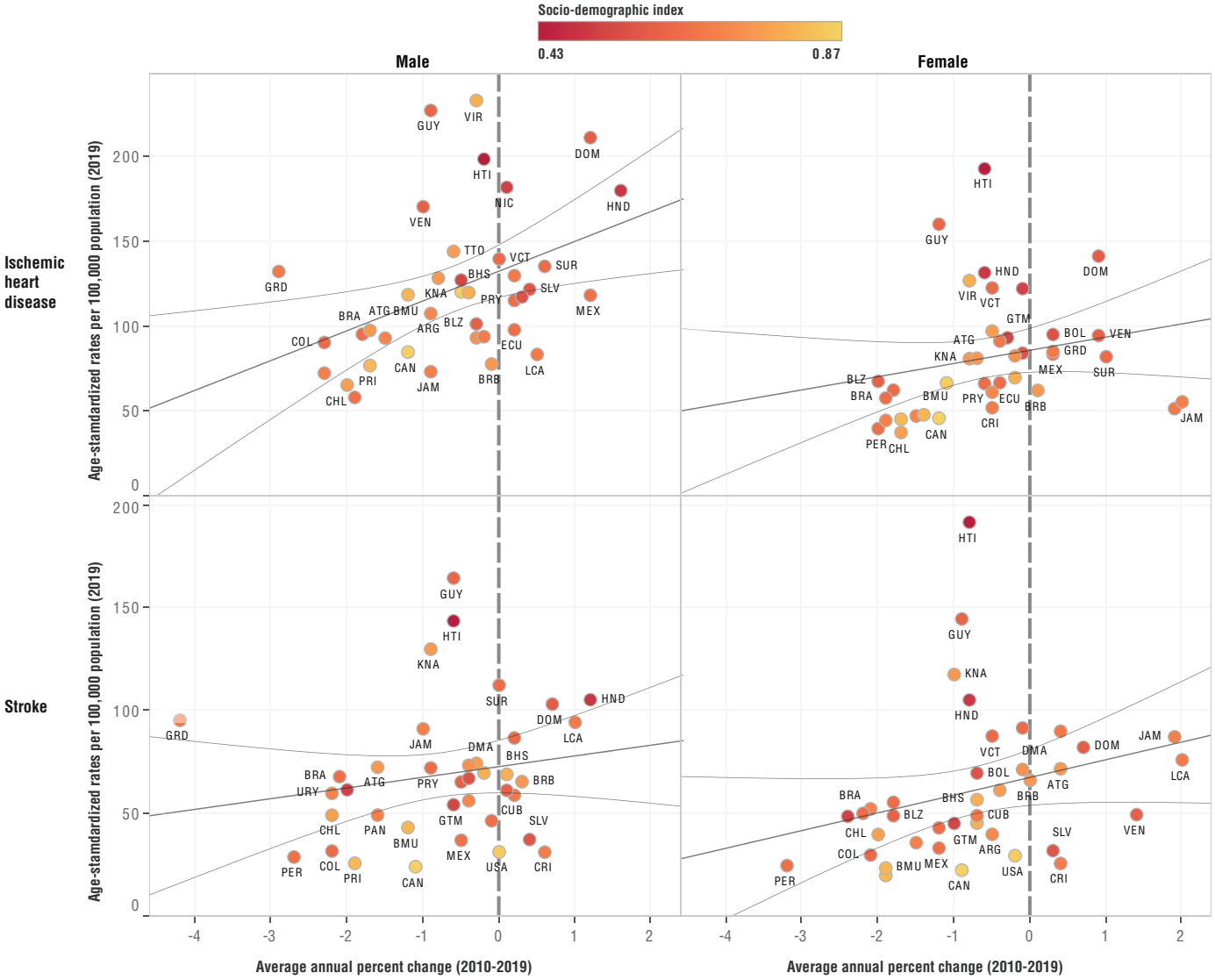
Source: prepared by authors based on data from the GBD Study 2019. Countries are ranked in descending order by the level of age-standardized death rates due to IHD and stroke combined in each sex. Bars are breakdown by cause, including ischemic heart disease and stroke subtypes: ischaemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage.
GBD, Global Burden of Diseases and Risk Factors Study

Nationally between 1990 and 2019, the ASDR for IHD and stroke decreased more in countries with a high or medium-high SDI than in lower SDI categories. However, the differences in ASDR between countries in the medium and medium-low SDI categories were not significant (see Figure S1, in supplementary material). Figure S2, panels A (IHD) and B (stroke) in supplementary material shows the AAPC in ASDR from 1990 to 2019 by sex and country. Again, the differences between countries were remarkable. Although few countries increased IHD mortality during this period, very few achieved reductions higher than 3% per year. Similar patterns were observed in stroke mortality. Additional data by disease, sex and location are provided in Table S1, in supplementary material.

Prevalence of hypertension and hypertension treatment cascade (awareness, treatment, control among treated, control in the population)

Figure 3 shows the hypertension care cascade, both the regional trend (1990-2019) and by country and sex in 2019. In the Region, prevalence of awareness, treatment, and control improved from 1990 to 2019. Indeed, in 2019, 69.8% (95%

FIGURE 2. Age-standardized death rates due to ischemic heart disease and stroke in 2019 and corresponding average annual percent change in the period 2010-2019 by sex in countries of the Americas



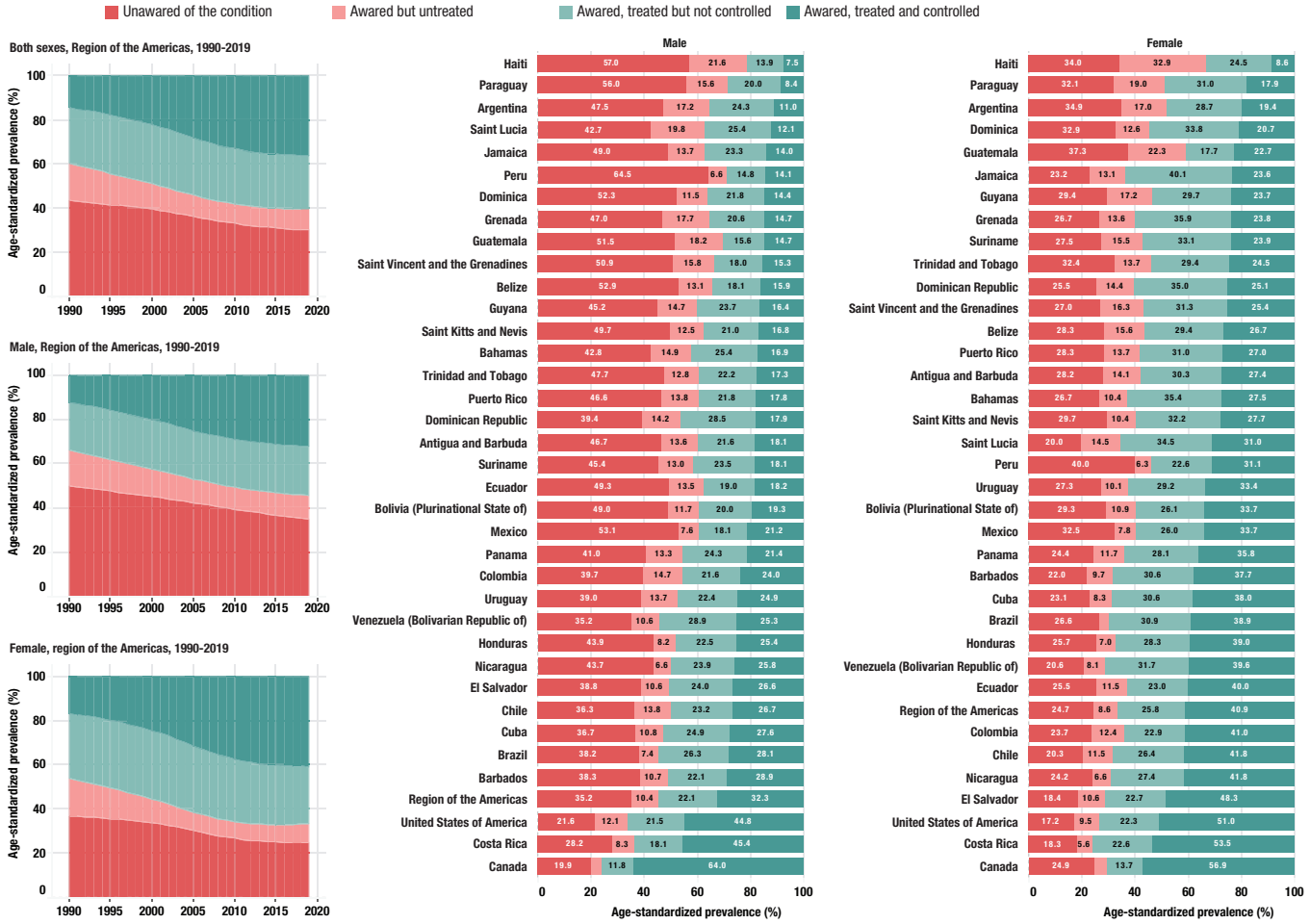
Source: prepared by authors based on estimates from the GBD Study 2019 and results from this study. Each dot represents a country that is color-coded by the socio-demographic index (SDI) from a low of 0.43 to a high of 0.87. SDI ranges from 0 to 1 where 0 represents the low level of socio-demographic development and 1 represents the high level of sociodemographic development. Countries are labeled using the ISO alphabetic code. The best fitted linear regression equation and 95% credibility intervals (gray dashed lines) are overlaid to show the association between the level of mortality in 2019 and the average annual percent change in the period 2010-2019.
GBD, Global Burden of Diseases and Risk Factors Study

uncertainty intervals [UI]: 66.9-72.6) of people aged 30 to 79 years with hypertension reported a previous diagnosis of hypertension (awareness), 64.8% (60.5-68.8) of men and 75.3% (71.0-79.1) of women; 60.3% (57.0-63.6) of people with hypertension were treated, 54.4% (49.7-58.9) of men and 66.7% (61.7-71.3) of women; and 36.4% (32.1-40.6) of people with hypertension had effectively controlled hypertension, 32.3% (26.9-37.9) for men and 40.9% (34.5-47.2) for women. The largest increase was observed for population hypertension control with an AAPC of 3.2% (95% CI: 3.1 to 3.2), followed by treatment (1.4% [1.4 to 1.5]), and awareness (0.7% [0.7 to 0.8]) (Table S2 in the supplementary material).

Despite important improvements in population hypertension control (from 3% to 7% annually) in almost all countries of the Region between 1990 and 2019 (Figure S3 in supplementary material), in 2019, 25 out of 36 (69%) countries for men and 1 for women had 40% or more persons with hypertension unaware of their condition, and 21 out 36 (58%) countries for men and 3 countries for women had population hypertension control lower than 20% (Figure 3, Table S2 in supplementary material). Population hypertension control reveals substantial gaps across countries observing significantly better performance in countries with high SDI, strata where Canada and the United States are located (see Figure S4, in supplementary material).

Figure 4 shows the age-standardized prevalence of hypertension control in the population in 2019 and corresponding AAPC during the period 1990-2019 (Panel A) and 2010-2019 (Panel B) by sex. The trends for population hypertension control increased (AAPC > 0) both in men (around 5-6% annually) and in women (4-5% annually) from 1990 to 2019. Generally, countries with high AAPC tended to achieve high levels of controlled hypertension in 2019 as illustrated by Brazil and

FIGURE 3. Age-standardized prevalence of undiagnosed (unawareness) hypertension, aware but untreated, aware and treated but not controlled, and controlled hypertension by country and sex in 2019, and their trends in the Region of the Americas, 1990-2019



Source: prepared by authors based on data from the NCD Risk Factor Collaboration Study and results of this study. Countries are ranked in descending order by the level of hypertension control in the population of each sex. Bars are breakdown by hypertension treatment cascade measure, including the prevalence of people that are unaware that they have hypertension, people that are aware of the condition but are untreated, people that are aware and treated but uncontrolled hypertension, and people that are aware, treated and controlled hypertension.
NCD, noncommunicable diseases

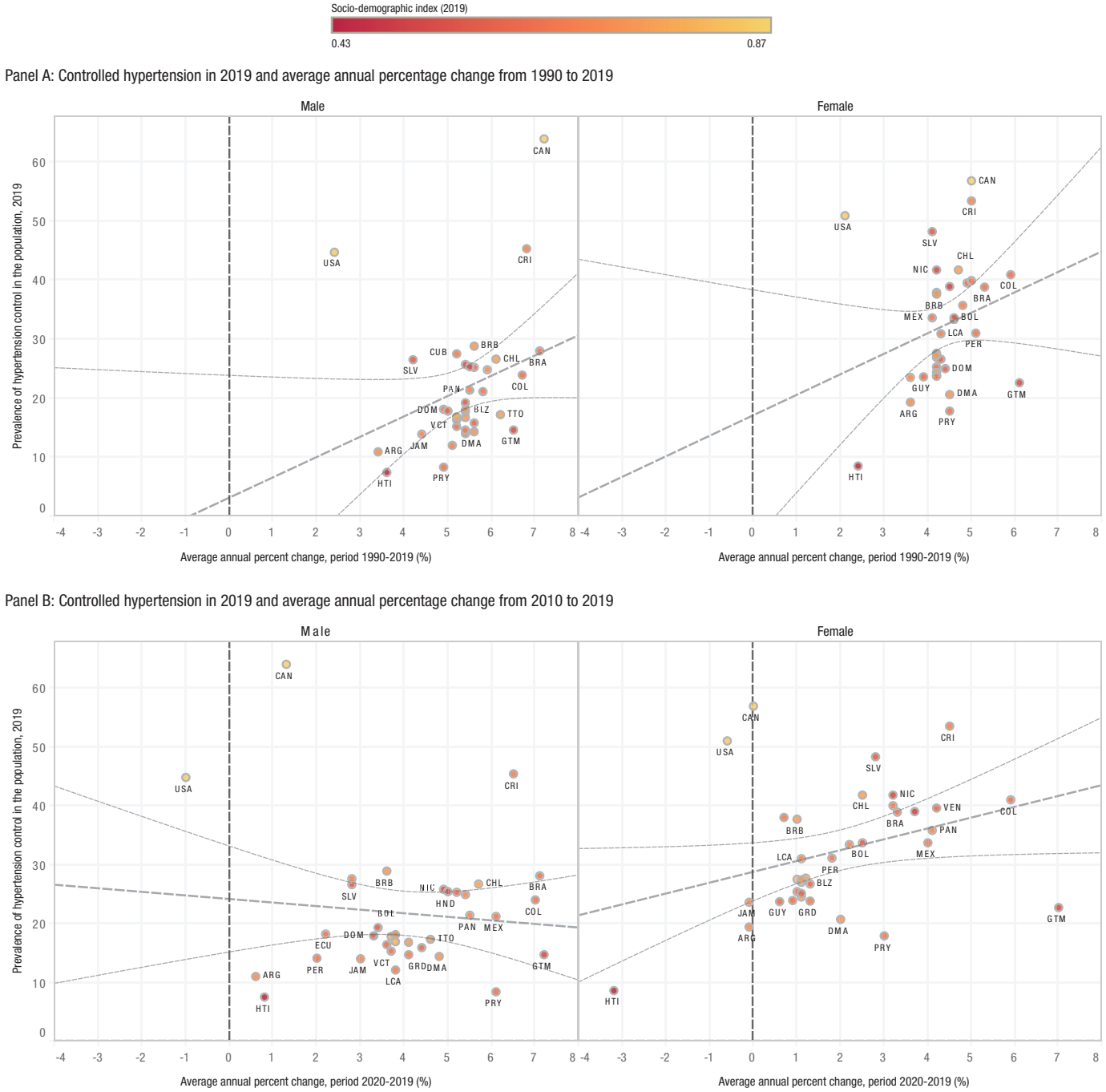
Colombia. Canada and Costa Rica are two outliers with a very high level of control. This pattern was less apparent in the latest decade (2010-2019) compared with the full period (1990-2019), mainly in men. For example, for men, the United States had a decreasing trend (AAPC < 0) but still had high controlled hypertension. In women, Argentina, Haiti, Jamaica, and the United States had decreasing trends (AAPC < 0), and of them, Argentina, Haiti, and Jamaica had low hypertension control. Although most countries had increasing rates, controlled hypertension remains suboptimal (Figure 4). Additional data on hypertension care cascade by sex and location are provided in Table S2, in supplementary material.

Association between hypertension control in the population and IHD and stroke mortality

Regionwide, during the period 1990-2019, the levels of IHD and stroke mortality, respectively, were inversely related to the prevalence of controlled hypertension among adults 30-79 years of each sex. We identified a strong ecological negative association, where 99% of the variations in the ASDR due to IHD and stroke could be explained by variation in population hypertension control, respectively, by sex (Table 2). A 1% increase in the prevalence of population hypertension control was associated with a reduction of 2.9% (95% CI: –2.94 to –2.85) in IHD deaths per 100 000 population, equivalent to an averted 25 639 deaths (2.5 deaths/100 000). The reduction was higher for men (–3.25% [–3.31 to –3.19]) compared with women (–2.66 [–2.70 to –2.61]). For stroke, a 1% increase in the prevalence of population hypertension control was associated with a reduction of 2.37% (–2.41 to –2.33) in deaths per 100 000 population, equivalent to an averted 9 650 deaths (1 death per 100 000 population), –2.79% (–2.85 to –2.72) for men and –2.06% (–2.10 to –2.02) for women.

Similar patterns were identified across countries, with some exceptions. For instance, IHD mortality and controlled hypertension showed a positive association –regression slope significantly higher than zero– by sex in the Dominican Republic, Honduras and Nicaragua. However, no evidence of association was observed in Ecuador, Mexico and Paraguay for

FIGURE 4. Age-standardized prevalence of hypertension control in the population in 2019 and average annual percentage change of hypertension control in the population in the period 1990-2019 and 2010-2019 by sex



Source: prepared by authors based on data from the NCD Risk Factors Collaboration Study and results of this study. Dots represent countries, which are labeled with ISO 3166-1 alphabetic character and color-coded by their corresponding socio-demographic index (SDI) in 2019.
NCD, noncommunicable diseases

men (see Table S3A, in supplementary material). For stroke, a positive association with controlled hypertension was observed in the Dominican Republic and Honduras in each sex (see Table S3B, in supplementary material). These exceptions coincide with countries where IHD and stroke mortality are increasing over time despite their improvement in hypertension control.

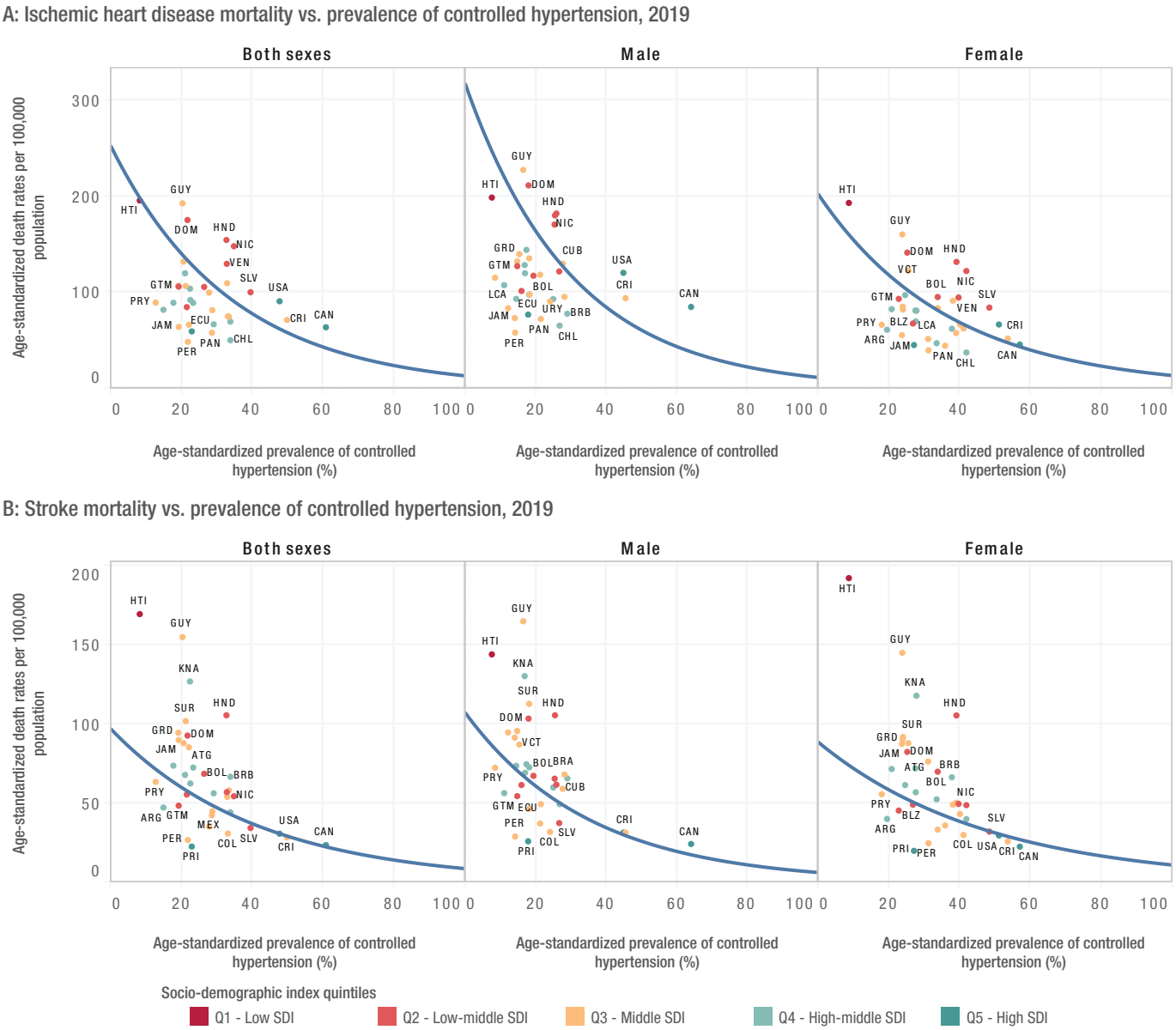
Estimates of IHD and stroke mortality versus hypertension control by sex and country in 2019, and the counterfactual region-wide scenario based on data from 1990 to 2019 are illustrated in Figure 5. There are countries with mortality significantly higher (low performance) and lower (high performance) than expected for their hypertension control. For example, among those with mortality significantly higher than expected due to

TABLE 2. Association the prevalence of controlled hypertension in the population and between ischemic heart disease and stroke mortality by sex, Region of the Americas, 2000-2019

Response variable	Explanatory variable	Sex	Slope (95% CI) (%)	Variation explained R2, %	Predicting model
ASDR (per 100 000 pop) due to ischemic heart disease	Prevalence of controlled hypertension in the population	Both sexes	−2.90 (−2.94 to −2.85)	99.84	$e^{[(-0.0294059 * HNTcontrol) + 5.5305]}$
		Male	−3.25 (−3.31 to −3.19)	99.75	$e^{[(-0.0330196 * HNT control) + 5.75908]}$
		Female	−2.66 (−2.70 to −2.61)	99.80	$e^{[(-0.0269537 * HNT control) + 5.30973]}$
ASDR (per 100 000 pop) due to stroke	Prevalence of controlled hypertension in the population	Both sexes	−2.37 (−2.41 to −2.33)	99.79	$e^{[(-0.0240177 * HNT control) + 4.57206]}$
		Male	−2.79 (−2.85 to −2.72)	99.64	$e^{[(-0.0282751 * HNT control) + 4.67247]}$
		Female	−2.06 (−2.10 to −2.02)	99.78	$e^{[(-0.0207928 * HNT control) + 4.48244]}$

Source: prepared by authors based on results from this study

FIGURE 5. Age-standardized death rates due to (A) IHD and (B) stroke versus the prevalence of controlled hypertension by sex in countries and territories in 2019, and the best-fitted regression model for the Region of the Americas over the period 1990-2019



Source: prepared by authors based on data from the GBD Study 2019, the NCD Risk Factors Collaboration Study and results of this study. Each dot represents a country, which is labeled by its ISO 3166-1 alphabetic code. Countries are color-coded by quintile of the socio-demographic index (SDI). SDI quintiles were computed based on the estimated SDI across 204 countries of the World in 2019. Lines (blue) represent the best fitted log-linear regression models of the annual age-standardized death rates due to IHD, and stroke on the prevalence of hypertension control for the Region of the Americas in the full period 1990-2019.
GBD, Global Burden of Diuseases; NCD, noncommunicable diseases

IHD, Nicaragua stands out in men and the Dominican Republic, Guyana, Honduras and Nicaragua in women. Additionally, for stroke, Guyana, Haiti, Honduras and Suriname stand out in men and women.

DISCUSSION

This study expands on previous research examining an entire Americas region over an extended time frame (5,6,20). It also provides insights into the hypertension treatment gap and compares countries' performance in hypertension control. Finally, it provides data on the ecological association between IHD and stroke mortality and population hypertension control regionally during the last three decades.

It is worth looking at the findings of this study through the lens of the hypertension care cascade. Hypertension detection/awareness is a proxy for access to health care. Hypertension control, specifically control among treated, relates to the ability of the medical care system to meet the standard of care, including access to effective medications and treatments. It is likely to reflect the ability of the health system to control other NCDs and health risks.

This new study confirms regional and national progress in reducing IHD and stroke mortality between 1990 and 2009. This progress was more remarkable in countries with higher levels of socio-demographic development; however, not all countries with high SDI achieved the same mortality improvement, an issue that deserves further studies. Such improvement has mainly been attributed to advances in public policies to reduce risk factors and programs to improve health care (21). Good examples are reducing tobacco consumption (22) and improving hypertension management (23).

Since the mid-2010s, the CVD mortality trend in the Americas has shown a slowdown in most countries, a plateau in several, but an increase in some countries (3,24). Notable examples of this pattern are the United States and Canada. Overweight and obesity (24), inequity in access to quality health care (25), including deficiencies in the clinical management of hypertension (26) have likely been key drivers of the recent slowdown and reversal of CVD mortality decline in the United States. In Canada, the slowdown in mortality has been attributed, in part, to the declining performance of that country's iconic hypertension program. Levels of hypertension control in women declined, and an increase in CVD mortality was observed (27).

Improvements in the detection, treatment, and control of hypertension have been documented worldwide between 1990 and 2019. Indeed, the Region of the Americas ranked second in performance after high-income countries (16). However, such improvements have been modest and very uneven. Most countries in the Region show poor performance in both diagnosis and control, and some traditional champions have regressed in their performance. Thus, after decades of progress, the decline in hypertension control rates at the population level in the United States (26) has caused the Surgeon General to sound the alarm and has called for an urgent reversal of this situation (28).

While socio-demographic development is critical to achieving better population health, the functioning of the health system is determined to optimize health outcomes. This study shows that countries with similar levels of SDI have substantial differences in hypertension control. Such differences can be attributed to how each of the countries approached or prioritized the control of hypertension. As described by others (29), factors influencing this variation include the country's financial resources, the extent of health insurance and health facilities, how frequently people interact with physicians and non-physician health personnel, whether a clear and widely adopted clinical guideline exists, and medicines' availability, among others significant health system barriers and facilitators (30).

The ecological study's strong association between population hypertension control and CVD mortality is plausible and consistent with previous observations. Indeed, both IHD and stroke are related to common risk factors: high blood pressure, tobacco smoking, and body mass index. Therefore, trends could be similar for both diseases (31). Indeed, population hypertension control strongly correlated with stroke and IHD mortality in Canada, England, and the United States (12). Moreover, the decline in stroke mortality in the United States was attributed to a combination of interventions and programs implemented to reduce stroke risks, the most likely being improved population control of hypertension (32).

Our study provides modelled new prediction equations to get the expected mortality for IHD and stroke based on a given level of hypertension control. These prediction equations are helpful for 1) assessing the care system performance in terms of its ability to avoid excess mortality for a given reached level of hypertension control; 2) getting insights on how much could be reduced IHD and stroke mortality for a set target increase in the hypertension control. For example, in the Region with a population of 1 010 339 327 people in 2019, by increasing the population hypertension control from 36.4% (level in 2019) to 50%, we could expect to reduce the death rates due to IHD from 86.5 deaths/100 000 (level in 2019) to 58.0 deaths/100 000 which translates into an averted 28.5 deaths/100 000 or 298 069 deaths. Similar estimation for specific location or population group can be done to estimate the potential impact of population hypertension control on CVD mortality using the PAHO **HTN:CVD EstimaTool** (https://www.paho.org/en/enlace/tool-estimate-impact-population-hypertension-control-cvd-mortality).

This study has some limitations. This is an ecological observational study. However, the direction of the ecological association between population hypertension control and cardiovascular mortality is solid and plausible. Moreover, it is consistent with data from other studies, including those with robust methodology, from our Region. For example, data from large cohorts from Cuba (33), Mexico (34) and South America (35) confirm the fundamental role of hypertension as the leading cause of CVD events, mortality and trends. Another limitation is the primary data sources for this analysis: GBD study (1) and NCD-RisC study (16). The GBD is a well-established and robust methodology that has been constantly improved, incorporates the most recent available data in each iteration, informs about the estimates' levels of uncertainty, and allows comparisons between countries over time (1). Importantly, in the case of the Americas, most of the countries have mortality statistics of acceptable quality and completeness (36), which allows for more precise estimates. On the other hand, NCD-RisC is a large epidemiological pooling study that includes studies with very heterogeneous study designs, sampling frames, and measurement methods that have provided important findings on trends in health and disease through its ongoing efforts to combine population surveys and other health metrics. Thus far, it is the best available data source on NCD risk factors globally.

However, some argue that in addition to the lack of detailed knowledge of the measurement protocols about a given data set, one of the main weaknesses of the NCD-RisC is the reliability of this approach to surveillance given the absence of empirical data in many countries included in their analysis (37). For example, we observed that some Central American countries had been ranked among the countries with good performance in population hypertension control. However, this finding does not seem very plausible because, in addition to the absence of NCD risk factors population-based surveys to support these data (16), some of these countries have low SDI and very fragile health systems that limit their ability to have effective hypertension management programs. Thus, not by chance, the CVD mortality trend observed in those countries collides with their supposedly good performance in controlling hypertension. Fortunately, despite these limitations and knowing that there is much room for improvement, more and more countries in this Region, including the most populous ones, have good quality and nationally represented population surveys (16) that make it possible to accurately estimate the prevalence of the main risk factors for NCDs, including those related to hypertension control.

In summary, this study found that IHD and ischemic stroke mortality accounted for a substantial percentage (more than 80%) of mortality from IHD and overall stroke combined in people of all ages and sexes. Also, there is a significant gap in detection/awareness, treatment, and control of hypertension in almost all countries. More importantly, a strong correlation between CVD mortality and population hypertension control was observed. Equally relevant is that the countries with the best performance in the population hypertension control over time show better progress in reducing mortality from CVD and lower mortality rates from IHD and stroke. This finding reveals the potential to reduce IHD and stroke mortality by effectively improving hypertension control in populations. Therefore, the systematic implementation of HEARTS in the Americas focused on the key drivers for hypertension control (38) is expected to optimize the program's effectiveness and improve hypertension control.

Modeled prediction equations are useful tools for assessing the performance of CVD health care, for prioritizing prevention strategies, and for informing programmatic and policy development. Moreover, the application of this study's findings boosted by the new WHO hypertension guideline, alongside greater political attention, universal access to health, and investment in primary care (39), can further reduce the CVD burden, reduce inequalities, and improve population health. Finally, bringing together in one piece the 30-year trend of CVD mortality and hypertension control in 36 countries of the Americas can substantially improve our understanding of a top-priority public health problem. At the same time, it becomes a powerful incentive to learn from the countries that achieved higher hypertension control rates with models for all populations.

Availability of data and materials. Data and supplementary materials are available online and from the corresponding author upon request. Data from the Global Burden of Diseases Study 2019 are publicly available through the GBD Results Tool (https://vizhub.healthdata.org/gbd-results/), and estimates of the prevalence of hypertension, and the hypertension treatment cascade are publicly available in the WHO Global Health Observatory, Noncommunicable diseases: Risk Factors page (https://www.who.int/data/gho/data/themes/topics/noncommunicable-diseases-risk-factors) and the NCD-RisC, Hypertension data download page (https://ncdrisc.org/data-downloads-hypertension.html). Data on the association between the prevalence of population hypertension control and ischemic heart disease and stroke mortality are available online in the PAHO **HTN:CVD EstimaTool** (https://www.paho.org/en/enlace/tool-estimate-impact-population-hypertension-control-cvd-mortality).

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Asociación entre el control poblacional de la hipertensión y la mortalidad por cardiopatía isquémica y accidente cerebrovascular en 36 países de la Región de las Américas, 1990–2019: estudio ecológico

RESUMEN

Objetivo. Cuantificar la asociación entre la prevalencia de control poblacional de la hipertensión arterial y la mortalidad por cardiopatía isquémica y accidente cerebrovascular en 36 países de la Región de las Américas entre 1990 y el 2019.

Métodos. Este estudio ecológico emplea la prevalencia de la hipertensión, la concientización, el tratamiento y el control poblacional de la hipertensión producidos por la Colaboración sobre Factores de Riesgo de las Enfermedades No Transmisibles (NCD-RisC) y estimaciones de mortalidad por cardiopatía isquémica y accidente cerebrovascular del Estudio sobre la Carga Mundial de Enfermedad del 2019. Se realizó un análisis de regresión para evaluar las tendencias temporales y la asociación entre el control poblacional de la hipertensión y la mortalidad.

Resultados. Entre 1990 y el 2019, las tasas de mortalidad estandarizadas por edad a causa de cardiopatía isquémica y accidente cerebrovascular disminuyeron en 2,2% (intervalos de confianza de 95%: –2,4 a –2,1) y 1,8% (–1,9 a – 1,6) anual, respectivamente. La tasa de reducción anual de la mortalidad por cardiopatía isquémica y accidente cerebrovascular se redujo a –1% (–1,2 a –0,8) entre el 2000 y el 2019. Del 1990 al 2019, la prevalencia de hipertensión controlada para una presión arterial sistólica/diastólica de ≤140/90 mmHg aumentó anualmente en 3,2% (3,1 a 3,2). Se observó una relación inversa entre el control poblacional de la hipertensión y la mortalidad por cardiopatía isquémica y por accidente cerebrovascular, respectivamente, en toda la Región y en los 36 países, a excepción de tres. En toda la Región, por cada aumento de 1% en el control poblacional de la hipertensión, nuestros datos predijeron una reducción de 2,9% (–2,94 a –2,85) en las muertes por cardiopatía isquémica por 100 000 habitantes, equivalente a 25 639 muertes evitables (2,5 muertes por 100 000 habitantes) y de 2,37% (–2,41 a –2,33) en las muertes por accidente cerebrovascular por 100 000 habitantes, equivalente a 9 650 muertes evitables (una muerte por 100 000 habitantes).

Conclusiones. Existe una sólida asociación ecológica negativa entre la mortalidad por cardiopatía isquémica y accidente cerebrovascular y el control poblacional de la hipertensión. Los países con mejor resultado en el control de la hipertensión mostraron un mayor progreso en la reducción de la mortalidad por enfermedad cardiovascular. Los modelos de predicción tienen implicaciones en el manejo de la hipertensión en la mayoría de los grupos poblacionales de la Región de las Américas y otras partes del mundo.

Palabras clave Determinación de la presión sanguínea; hipertensión; enfermedades cardiovasculares; enfermedades no transmisibles; Américas

Associação entre controle populacional da hipertensão e mortalidade por doença cardíaca isquêmica e acidente vascular cerebral em 36 países das Américas, 1990-2019: um estudo ecológico

RESUMO

Objetivo. Quantificar a associação entre a prevalência de controle populacional da hipertensão e mortalidade por doença cardíaca isquêmica (DCI) e acidente vascular cerebral (AVC) em 36 países das Américas, de 1990 a 2019.

Métodos. Este estudo ecológico utilizou os dados de prevalência da hipertensão e prevalência da detecção, tratamento e controle populacional da hipertensão do estudo NCD-RisC, e de mortalidade por DCI e AVC do Estudo de Carga Global de Doença de 2019. Análise de regressão foi utilizada para avaliar as tendências no tempo e a associação entre controle populacional da hipertensão e mortalidade.

Resultados. Entre 1990 e 2019, as taxas de mortalidade padronizadas por idade devidas a DCI e AVC diminuíram anualmente 2,2% (intervalos de confiança de 95%: −2,4 a −2,1) e 1,8% (−1,9 a −1,6), respectivamente. A taxa anual de redução na mortalidade por DCI e AVC desacelerou para −1% (−1,2 a −0,8) durante o período de 2000-2019. De 1990 a 2019, a prevalência de hipertensão controlada com pressão arterial sistólica/diastólica ≤140/90 mmHg apresentou aumento anual de 3,2% (3,1 a 3,2). O controle populacional da hipertensão apresentou associação inversa com mortalidade por DCI e AVC, respectivamente, em toda a região, e em todos os 36 países, com a exceção de três. Em toda a região, para cada 1% de aumento no controle populacional da hipertensão, nossos dados previram uma redução de 2,9% (−2,94 a −2,85) nos óbitos por DCI por 100 000 habitantes, equivalente à prevenção de 25 639 óbitos (2,5 óbitos por 100 000 habitantes), e de 2,37% (−2,41 a −2,33) nos óbitos por AVC por 100 000 habitantes, equivalente à prevenção de 9 650 óbitos (1 óbito por 100 000 habitantes).

Conclusão. Existe forte associação ecológica negativa entre mortalidade por DCI e AVC e controle populacional da hipertensão. Os países com o melhor desempenho no controle da hipertensão mostraram melhor progresso na redução da mortalidade por doenças cardiovasculares. Os modelos de previsão têm implicações no controle da hipertensão na maioria das populações da Região das Américas e em outras partes do mundo.

Palavras-chave Determinação da pressão arterial; hipertensão; doenças cardiovasculares; doenças não transmissíveis; América